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THE IMPERIAL COLLEGE OF TROPICAL AGRICULTURE, TRINIDAD, B.W.I.

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COMMERCIAL RESEARCH

AN address* delivered by Dr. E. K. Bolton (Chemical Director of E.I. du Pont de Nemours & Co.), on the occasion of his receiving the Perkin Medal of the American section of the Society of Chemical Industry, makes inspiring reading; and its message to all classes of research workers seems to us to be one of real importance. Dealing with the history, growth and organization of du Pont research, Dr. Bolton shows how difficulties and setbacks, inevitable in the early stages of any research programme, have been met and overcome by the industry, vision and patience, both of the research workers themselves and the principals of the firm. A research policy which has produced the outstanding results summarized in Dr. Bolton's address clearly justifies itself, and a brief consideration of its details would appear well worth while.

In so doing, we need not concern ourselves with the earliest days of du Pont research, interesting though they are and important as are the results which were achieved. It is perhaps significant, in view of later developments, to note that the founder of the firm, Eleuthene Irenee du Pont de Nemours, was a pupil of the famous Lavoisier. Certainly the enterprise was built on sound foundations.

The establishment and subsequent abandonment of a Centralized Chemical Department "to take care of all research activities of the Company", is however, worthy of our attention. After 10 years trial, this arrangement was discarded in favour of that which now prevails. This in outline, is as follows. Each Manufacturing Department now has its own Research Division and this Research Division is responsible only to the general manager of its Manufacturing Department. The staff of the old Chemical Department which remained after these research divisions had been established, was then organized into a central Chemical Department. This department is wholly independent of any manufacturing department, and reports directly to the President and Executive Committee: it is engaged in pioneering applied and fundamental research and its results flow into the various research divisions. It is not hampered by the daily problems arising from manufacture, though naturally it is influenced to some extent by the background and experience of the manufacturing divisions: there is thus little likelihood of

Chemistry and Industry No. 16, April 21st, 1945.

attractive opportunities being neglected because they do not come within the immediate interests of the Manufacturing Departments.

The types of research pursued at du Pont clearly apply primarily to the needs of this company only and need not then be considered in detail. We should note, however, that fundamental research is given equal standing with the other two branches—improvements in existing processes and products, and the development of new products. Fundamental research into the problems of colloid chemistry, physical chemistry, organic chemistry and physics is felt to be "one of the most valuable phases of research work", even though the prospects of immediate practical gains from this type of work may seem small.

The research policy which is the motive force behind this considerable organization is logical and far-sighted. The five cardinal points upon which it is based are applicable to research organizations of every kind and in every place. They are :—

(1) Research is looked on as a major rather than a minor activity. It flourishes in an atmosphere of "appreciation, encouragement, liberality and patience". That this attitude should prevail in a commercial firm where the results of research are easily assessed in terms of commercial value, speaks for itself.

(2) Continuity. "Research" says Dr. Bolton "should not follow a profit or loss curve". Both nylon and neoprene were children of the depression.

(3) Strong central research department. This is devoted to long-range investigations. It is primarily concerned with the future.

(4) Staff. Only the very best men are secured.

(5) Teamwork. The research activities of the many divisions are co-ordinated by the Chemical Department.

The results of du Pont research have been so outstanding as to make a detailed consideration unnecessary. Many products which have been pioneered by the research departments of this firm are now household words. Nylon and neoprene(s ynthetic rubber) are two that spring to mind, but no less outstanding has been the Company's work on dyes (here Dr. Bolton once more attributes success to the expenditure of large amounts of capital during the profitless years), moisture proof cellophane, ammonia and other products of high-pressure synthesis, and Duco nitrocellulose lacquers.

Our brief survey of Dr. Bolton's address, has brought us to the point where it is necessary to point the moral. In its diversity of aims, and, in the necessity for placing its products successfully on an open and competitive market, du Pont research faces problems common to many seemingly widely different forms of research enterprise. It is not too much to suggest that the success with which this Company has attained its many objects, springing as it does from the organization and policy which we have outlined, could be duplicated, using similar methods, in other spheres. The five points of the du Pont research policy might well stand as the guiding principle of an Agricultural Department's research policy. The courage displayed in adversity and the willingness to continue researches which are for the moment yielding no cash return, may well provide food for thought for any Government. No less telling is the emphasis placed upon long term and, especially upon fundamental research.

Here then are the means adopted by a firm, not interested in science for science's sake, and here beside them is the end achieved. Surely together they constitute a fitting and adequate answer to those critics of research (commoner perhaps in the Colonies than any where else in the world) whose constant cry is "What is the use"? and who look upon "pure" research as a pleasant pastime to be indulged in by the intelligentsia at the expense of people and Government.

EFFECT OF HORMONES ON PLANT DEVELOPMENT

Since it has been shown that synthetic growth substances will supply the stimulus necessary for continued ovary development and hence fruit development in a number of plants, various attempts have been made to increase 'fruit set' in both 'fruits' and vegetables by the use of hormones. These attempts have met with varying degrees of success. L. Greene (*Proc. Amer. Soc. Hort. Sci.*, 42, 149; 1943) finds that a number of growth substances applied as sprays, lanoline pastes and injections to Starking apples failed to increase fruit set.

Similar negative results are reported by C. S. Pomeroy and W. W. Aldrich (*ibid.*, 42, 146; 1943) using naphthyl acetic acid on orange and grapefruit, although with the Marsh grapefruit used, pollen of other grapefruit varieties did increase the set of fruit; on the other hand, R. H. Roberts and B. E. Struckmeyer (*ibid.*, 44, 417; 1944) found that aqueous solution of β-naphthoxy acetic acid and 2 : 4 dichlorophenoxy propionic acid sprayed on to tomato flowers induced fruit setting. *O*-chlorophenoxy propionic acid was less effective but both phenoxy-acids caused distortion of the foliage.

The use of the sprays did not prevent fruit or flower abscission due to virus or to nutritional deficiencies. Favourable results from the use of these sprays were also found with pumpkins, outdoor cucumbers, egg-plant and *Nicandra physaloides* but not with apple (nine varieties), greenhouse cucumbers, peppers, potatoes, or strawberries.

In field experiments of a similar nature carried out by A. E. Murneek, S. H. Wittwer and D. D. Hemphill (*ibid.*, 44, 428; 1944) on snap beans, using naphthylacetamide and naphthoxy-acetic acid applied as a spray to the plants every second or fifth day, increases in fruit yields were obtained in hot years, but decreases in cold years, emphasizing the importance of environmental conditions in determining the nature and extent of response to the treatments. (*Nature*, Vol. 155, No. 3928, p.185, 1945.)

PRELIMINARY GRAZING TRIALS IN TRINIDAD

BY

K. R. M. ANTHONY AND J. D. HUNTER-SMITH

(Adapted from a dissertation presented in part fulfilment of the requirements for the Associateship of the Imperial College of Tropical Agriculture.)

Introduction

A conspicuous feature of the Agriculture in Trinidad is the absence of any high quality pastures. Most of the rough grazings are little more than waste ground which has been left to re-establish natural vegetation. This gives rise to a miscellaneous collection of species including many shrubs and semi-shrubs. To supplement these poor natural pastures the common practice is to stall feed fodder grasses, the most widely cultivated being Elephant grass (*Pennisetum purpureum* Schum.) and Guatemala grass (*Tripsicum laxum* Nash). Research has hitherto been devoted to finding the best methods of propagation, cultivation and management of these grasses under the soiling system.*

If it were found possible to graze, instead of soil, a fodder grass known to thrive in the Island, there would be certain important advantages to the farmer. An economic advantage would be the elimination of the cost of cutting and carting to the byre. Paterson (1942) estimated that, on the College Farm, 60 per cent. of the total outlay on a field of fodder grass represents the daily cutting, carting and feeding of the green herbage. The cost of storing and carting the manure has also to be considered. With consistently increasing labour costs, these expenses, incurred under soiling but not under grazing, may become an over-riding consideration in the estate management. For the peasant the cost of his own labour is of less importance. However most of these small cultivators do not possess carts and the distance that grass and manure can be hand carried is very small. Often his land is widely scattered; his cow remains near the dwelling and the arable land is a mile or so away. This discourages the cultivation of high yielding fodders and encourages waste of manure because of the labour of carrying it from the byre to where it is needed. Failing a reallocation of holdings, a solution to this problem would be found if it were possible to graze a fodder grass.

A proviso of the fore-going advantages is that the cattle and the grasses do not suffer as a result of grazing. This paper deals with preliminary trials made on the two main fodder grasses, grown on the College Farm, *viz.*: Elephant grass and Guatemala grass, to test their ability to withstand the effect of the grazing animal.

* Paterson 1933, 1935, 1936, 1938.

Small Plot Elephant and Guatemala Grass Trial

Experimental details. Each grass was subjected to the following three treatments on triplicated plots over a period of seven months.

(1) Grazing at six weekly intervals
(2) Alternate cutting-and-grazing at six weekly intervals
(3) Cutting at six weekly intervals

The animals used for grazing were three-quarter bred Holstein-Zebu heifers and they were confined on small 1/33rd acre plots by means of an electric fence.

Results. A difference between Guatemala grass and Elephant grass in their ability to withstand grazing soon became apparent. Whilst with Elephant grass no stool mortality due to grazing occurred, in the case of Guatemala grass it was severe. Counts made before the first and after the fourth, or last, grazings of Guatemala grass showed the stool mortality to be as follows:—

Grazed plot ...	.. 27%
Cut-and-grazed plots	.... 9%
Cut plots ...	.... 7%

Tiller counts, on Guatemala grass, taken at the same times on 10 per cent. of the total stools showed a decrease of:—

Grazed plots	...61.2%
Cut-and-grazed plots	...47.4%
Cut plots ...	...35.7%

These figures, in conjunction with the photographs taken eight weeks after the end of the experiment (*see* Figs. I, II and III) show that Guatemala grass was unsuited to grazing under the system of management adopted. The reason for its unsuitability is associated with the thick, tough midrib, the shallow rooting and insecure attachment of the tillers. During the latter part of each grazing the cattle could be seen tugging at the leaves in an effort to bite them through. Some times they were successful, but if not, either the blade slipped between the teeth and the upper gum or a tiller was uprooted. No trouble of this nature was observed in the case of Elephant grass.

Field Scale Elephant Grass Trial

The small plot experiment with Elephant grass suffered to some extent from the depredations of Froghoppers (*Tomaspis saccharina*). Never-the-less observations indicated it to be promising forage and prompted the following field scale grazing trial.

The field was originally intended for soiling and so the spacing and cultural treatments were those normally adopted on the College Farm *i.e.* stem

cuttings planted at 2 x 3 feet and artificials applied at three hundredweights per acre per annum. One acre was fenced off into four equal plots which were grazed rotationally. As there was no water or shade in the field the management had to be adapted accordingly. The dairy herd was turned into a plot about 8 a.m., after the morning milking, and taken out between 10 and 11.30 a.m. when the byre had been cleaned out. This arrangement fitted in well with the grazing habits of the animals because after two or three hours of steady grazing there was a pause for rumination. Also by 11 a.m. in Trinidad the sunlight is intense and the cattle naturally seek shade.

The first grazing took place four months after establishment. In general, throughout the trial, the height of the grass at the beginning of grazing was between five and six feet and it was eaten down to between two and three feet. However there was considerable irregularity in height within the plots, especially at the later grazings. Individual stools ranged from four to seven feet before grazing and three inches to three feet six inches after grazing. There were also occasional flowering culms which shot up to eight to ten feet and remained uneaten. The unevenness became progressively worse, because a stool only partially eaten at one grazing was still less likely to be eaten at the next.

The cause of selective grazing must presumably be associated with uniformity of genotype and/or the degree of soil variation. With vegetative propagation the genotype would be homogeneous provided all the planting material is selected from the same strain. In the plantings on the College Farm there exists two types:—(1) *Pennisetum purpureum* var. Uganda which was introduced from Africa because of its resistance to *Helminthosporium* leaf spot, and (2) the 'Original' type which was cultivated locally before the Uganda introduction. The two strains can be distinguished by the sparsely pubescent culm and densely pubescent, variegated leaves of the var. Uganda, whilst with the 'Original' type the culm is densely pubescent and the leaves are almost glabrous. It is important for uniformity in grazing that one of these strains alone should be planted. It is recommended that the choice should be the Eye-spot resistant var. Uganda because during the present experiment there was a slight attack of *Helminthosporium* sp. which curtailed the growth of the 'Original' type and encouraged selective grazing.

As the trial proceeded the average height to which the cattle grazed gradually increased from about two to three feet. This was because the lower, uneaten residue became fibrous and increased in length slightly during the interval between each grazing. New succulent growth was made only from the upper nodes. Thus by the third grazing the stools consisted of a 'bunchy-top' supported on cane-like stems (*see* Fig. V). In order to remove these fibrous stems and to obtain renewed palatable herbage from the base of the stool the plots were cut back to ground level after the fourth grazing. It is considered that this will be necessary twice yearly; and in conjunction with the establishment of a single strain and the use of small paddocks, so as to minimise soil variability, it should not be necessary to cut back stools to a uniform height after each grazing in order to obtain a uniform stand.

The difficulties in the management of the pasture have been stressed and methods of overcoming them stated. However the most important feature of the trial was that no damage to the stools resulted due to grazing and trampling. By a system of part-time grazing good pasturage was obtained without any capital outlay in providing water or shade and only a small outlay on fencing. The dairy herd, which varied in numbers during the trial from five to ten cattle, grazed any one paddock in two to four days. During the interval between finishing one paddock and beginning the next they were turned into the rough grazing field. The consumption of stall fed fodder subsequently consumed in the byre dropped by approximately 50 per cent. when the cattle spent from 8 a.m. to 11 a.m. in the Elephant grass pasture. During 166 days of the trial 290 unit cattle days grazing were provided, but it should be noted that this experiment does not permit of the working out of exact figures for carrying capacity.

The field is being continued as a pasture. At the present time, after seven months of rotational grazing, the stand is looking as healthy and robust as it did at the beginning.

Indigofera endecaphylla as a Ground Legume

The value of an Elephant grass pasture would be greatly enhanced if a suitable, high protein legume could be found to grow in association with it. In this connection, during the preliminary phase of these experiments, some Guatemala grass, on the College Farm, was observed to be acting as a cover crop for a small area of *Indigofera endecaphylla* which had survived from a previous planting. It was decided to try to establish this legume between the stools of Elephant grass in the field grazing trial.

Indigofera was recently introduced into Trinidad as a promising legume. In Puerto Rico, Davis and Villalobas (1940) showed, by chemical analysis, its probable high value as a stock feed. The chemical composition, including protein content is strikingly similar to alfalfa in the pre-bud stage (*see* Table I).

Table I

Dry Basis

	Indigofera %	Alfalfa (Wood and Woodman 1939) %
Crude protein	19.6	20.5
Ether extract ...	4.3	2.3
Crude fibre	27.2	28.2
N-free extract ...	39.0	40.9
Ash	9.8	8.2

GUATEMALA GRASS PLOTS.

APPEARANCE EIGHT WEEKS AFTER THE END OF THE EXPERIMENT.

FIG. I.—Treatment (*a*) Rotational grazing.

FIG. II.—Treatment (*b*) Alternate cutting and grazing.

FIG. III.—Treatment (*c*) Rotational cutting.

FIG. IV.—The dairy cows beginning the grazing of a paddock.

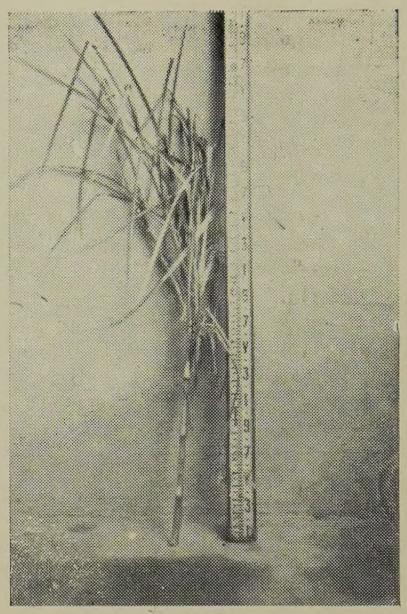

FIG. V.—A typical tiller produced after three rotational grazings. Note the long cane-like stem which below 2 ft. 6 ins. is woody and unpalatable.

FIG. VI.—Grasses (*Paspalum conjugatum* and *Paspalum fasciculatum*) in foreground growing in association with Indigofera.

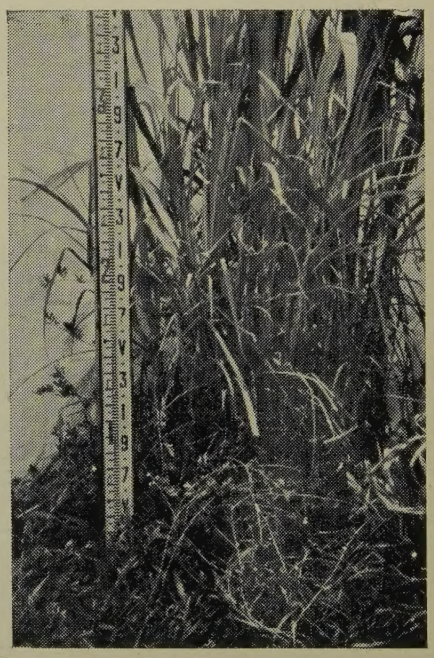

FIG. VII.—Indigofera climbing stool up to 2 ft.

Indigofera growing round a stool of Elephantgrass. Both photographs taken at the end of the dry season after 3 grazings.

Establishment. A small area of Indigofera, 1/16 acre, was established between stools of Elephant grass planted two weeks previously. This was done by laying mature, creeping stems in shallow drills 18 inches apart. The bases of the stems were then covered loosely with soil. In this way two rows were planted between consecutive rows of Elephant grass. The establishment was successful and a good cover was produced in three months.

Grazing. By the first grazing, which occurred at the end of November, the Indigofera had been spread uniformly between the stools giving a luxuriant mat two feet tall (*see* Figs VI & VII). After grazing it presented a patchy appearance but in the interval between grazings made a remarkable recovery. By the following June weeds were showing signs of encroachment especially Sour grass (*Paspalum conjugatum*). This weediness is difficult to overcome because of the spreading habit of the legume. The same problem was encountered when a pure stand of the legume was grazed in another field. There it was found that weed encroachment was more severe with grazing than cutting.

With the exception of this disadvantage, namely the difficulty of maintaining Indigofera as a pure stand, the Elephant—Indigofera pasture showed great promise. A large acreage is being planned on the College Farm. Besides Indigofera, *Brachiaria decumbens* is a possible bottom grass for growing beneath the stools. It has the advantage of producing a dense cover to the exclusion of weeds. It is possible that for this combination the Elephant grass stool should be more widely spaced. In this and many other ways there is great scope for future investigations.

Summary

A study was made of the effects of grazing Guatemala grass, Elephant grass and Indigofera interplanted amongst Elephant grass.

Guatemala grass was found to be unsuitable as a forage grass. The thick, stout midribs rendered it extremely difficult for cattle to break off leaf blades. This, combined with the shallow rooting system and insecure attachment of tillers, led to uprooting. Grazing resulted in reduction of tillering and severe stool mortality.

A small plot experiment indicated the suitability of Elephant grass as a forage and prompted a field scale grazing trial.

Four ¼-acre Elephant grass paddocks were rotationally grazed. Grazings were commenced when the grass was between five and six feet high and it was eaten down to between two and three feet. Any one paddock was grazed in two to four days. No damage resulted to stools either from grazing or trampling.

It was emphasised that for uniformity of grazing, planting material of homogeneous genotype must be used. The desirability of using a strain resistant to *Helminthosporium* leaf spot was stressed.

Indigofera endecaphylla, interplanted between Elephant grass stools, showed great promise, but the difficulty of maintaining a pure stand was noted.

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EXTENSION OF GUAVA PRODUCTION TO CALIFORNIA

According to a paper by H. J. Weber published in the *Proc. Amer. Soc. Hort.* 41 : 228-33, guava thrives on almost any type of land and there are thousands of acres which could be planted with this fruit, the only limiting factor being cold. At Riverside Experiment Station the guavas are slightly scorched by frost every 3 or 4 years and have been severely frozen back twice in 25 years. The severely frozen trees made a good recovery, especially those which were cut back to the ground immediately after the frost, and only one year's crop was lost. There is considerable variation between plants in resistance to the lighter frosts; a heavy frost affects all alike, though a few progenies are tender enough to be killed outright. Such types need not be propagated. There are very few clonal varieties, since propagation is usually by seed. Vegetative propagation by root cuttings is the most rapid way of producing clonal plants on their own roots and such plants do not need to be reworked if cut to the ground by frost. Owing to the great variation commercial plantations should not be made from seedlings. The guava is very high in ascorbic acid, the 6 varieties examined at Riverside containing from 164 to 971 mg. per 100 c.c. in the expressed juice. Except in the case of Rolfs, the richest in ascorbic acid, the white fleshed fruits had a higher ascorbic acid content than the red. Although this confirms findings of other workers the author considers this was probably due to chance selection of red types normally low in ascorbic acid. A great commercial future, it is suggested, awaits the dehydrated product.

OBSERVATIONS ON MOLE CRICKETS AND THEIR CONTROL IN TRINIDAD, B.W.I.

BY

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Introduction and Nature of Damage

Mole crickets are among the most destructive of all pests of vegetable gardens and lawns in Trinidad. *Scapteriscus vicinus* Scudder is by far the more abundant of the two species occurring in the island and ranks as a major pest. The other species, *Gryllotalpa hexadactyla* Perty, is rarely sufficiently numerous to cause extensive damage.

Mole crickets normally live just below the surface of the soil, and are more prevalent in sandy soils. Their extensive burrowing may result in the destruction of seed-beds or the uprooting of young plants. They feed on the roots and other underground parts of many plants, showing a preference for tender young growth, and are especially destructive to seedlings and recently transplanted tomatoes, cabbages, cauliflowers and other vegetables. Tobacco and groundnuts are also sometimes seriously damaged. Lawns are often attacked and the grass may be destroyed in patches. When feeding at soil level, mole crickets cut through the stems of young plants, simulating the damage caused by cutworms. When they feed from below, young plants are often pulled down into the soil in a highly characteristic way leaving only the tops of the leaves visible above the ground. Mole crickets are seldom seen during the day, as their burrowing and feeding activities are nocturnal. They are capable of flight and are often attracted to artificial lights. At certain times of the year, in Trinidad notably in November and December, they are on occasion very prevalent at lights following heavy rain.

Life-History

In *Scapteriscus vicinus* the eggs are laid by the female mole cricket in earthen cells which she constructs in the soil from 2 to 6 inches below the surface. Normally 3 or 4 separate egg chambers are constructed by each female. About 30 to 35 eggs are usually laid in each cell. As many as 42 eggs have been found in a single egg chamber in Trinidad. They are ovoid, greenish-grey in colour and measure 3.0 mm. in length and 2.5 mm. in width. After egg-laying the cell containing the eggs is tightly closed with earth by the female. Prior to hatching the eggs increase somewhat in size and become yellowish-white in colour. They hatch in about 18 to 30 days depending on temperature.

The nymphs or young mole crickets are at first white but soon darken to become pale brown in colour. For several days they remain within the egg chamber and do not feed. Young nymphs found together in a group in an earthen cell in Trinidad measured 5.0 mm. in length. Later they become more active, burrowing through the soil and feeding together. At first they seem to be gregarious but later scatter in all directions. The nymphs feed in the same way as the adult mole crickets, from which they differ only in respect of size and in being wingless. They grow slowly and after 8 moults, probably spread over 6 or more months, reach the adult stage. The adult mole cricket measures about 4.5 cm. in length.

Natural Enemies

Mole crickets have numerous natural enemies. In Trinidad these include the giant toad, *Bufo marinus* (L.), which feeds voraciously on nymphs and adults, and various species of lizards and birds. In the Caribbean area mole crickets are apparently only found in a few of the islands, and in most of those in which they occur they are regarded as rare insects. Puerto Rico is a notable exception, where they are even more important pests than in Trinidad. This has justified an interesting attempt at biological control. Wolcott (1941) reports that the introduction from Brazil into Puerto Rico of *Larra americana* (Saussure), a wasp parasitic on mole crickets, has resulted in its successful establishment there. This parasitic wasp, together with two other closely related species attacking mole crickets, occurs rarely in Trinidad, but according to Adamson (1942) no significant control of these pests can be attributed to its activities.

A further parasite of mole crickets is the Tachinid fly, *Euphasiopteryx australis* Tns., reported by Wolcott (1940) from Brazil. Dr. G. N. Wolcott (1945, *in litt.*) informs me that an attempt is also to be made to introduce this parasite into Puerto Rico.

Control Methods

Attempts have been made to control mole crickets in many countries by cultural, mechanical, chemical and biological methods. These include ploughing to expose the eggs, flooding to drown the nymphs and adults, trapping of adults by light traps, the use of protective collars placed around plants, soil fumigation, the use of poison baits and biological control by means of parasites.

In Trinidad several methods of controlling these pests have been investigated. Various substances when applied to lawns are effective in bringing mole crickets to the surface. Carbon disulphide emulsion, ordinary disinfectant and a pyrethrum extract have been used. These should be watered directly into the lawn. On coming to the surface the mole crickets should be collected and destroyed. Pickles (1940) states that a carbon disulphide emulsion, used for the control of chinch bugs attacking lawns, drove numerous mole crickets to

the surface, where they died almost immediately. Kennard (1943) studied the effectiveness of protective collars and poison baits in protecting tomatoes from mole cricket attack. He found that the leaves of various plants gave excellent control, and Paris green and barium fluosilicate were effective in poison baits.

The writer made some preliminary experiments on the control of mole crickets in lawns using kerosene emulsion, orthodichlorobenzene emulsion and a proprietary soil fumigant consisting of a mixture of ortho- and paradichlorobenzene. The kerosene emulsion and orthodichlorobenzene emulsion were watered directly into the lawn. They were effective in bringing mole crickets to the surface, but caused severe scorching of the grass. The proprietary soil fumigant was applied in small holes about 18 inches apart made through the grass into the soil as recommended by the manufacturers. No mole crickets were brought to the surface. The repellent effect claimed for the product was difficult to assess. As it depends on volatization for its repellent action, it seems unlikely that this product would remain effective in the soil for very long with the temperatures prevailing under tropical conditions.

Protective Collars

Mole crickets can be prevented from attacking vegetables and other crops by the use of protective collars placed around the plants. As these pests feed either at soil level or just below the surface, the portion of the plant protected must be the stem at the point where it enters the soil together with any underground part of the stem and as much as possible of the root system.

This method has been successfully used in Puerto Rico for the protection of tobacco seedlings, leaves of mammee apple and cylinders of tin, heavy paper and wire mesh being used as protective collars. In Trinidad the large tough leaves of various plants have given excellent control. The leaves of mammee apple (*Mammea americana*), pomerac (*Eugenia malaccensis*), avocado pear (*Persea americana*) and other plants have proved suitable for this purpose. Stiff waxed paper and metal cylinders have also given effective protection. The leaves used should be about 9 to 10 inches in length by about 3 to 4 inches in width. Waxed paper or metal cylinders should measure about 3 to 4 inches in height by about 2½ inches in diameter. The leaves should be made into cylinders of approximately these dimensions.

Mole crickets are especially destructive to recently transplanted tomatoes, cabbages, cauliflowers and other vegetables, and the protective collars can often be most conveniently applied when seedlings are transplanted from the seed-bed to the field. The seedlings should be planted so that the protective collar is buried in the soil to a depth of some 2 to 3 inches with about one inch left projecting from the surface of the soil. Young plants already planted out in the field can also be effectively protected by placing the collar around the base of the plant and pushing it into the soil to a depth of about 2 to 3 inches.

Poison Baits

Control of mole crickets by poison baits is based on the fact that they come to the surface of the soil to feed at night, especially after heavy rain, and that they are attracted to and feed readily on bran and crushed grain. In the southeastern United States where mole crickets are serious pests, their control is advocated by the use of poison baits (Wisecup and Hayslip, 1943), and sodium fluosilicate mixed with wheat bran is recommended for this purpose. Similarly, in Europe for several years barium fluosilicate has been used in poison baits for the control of mole crickets. Kassab (1939) also reports that this substance is very effective against these pests in Egypt.

A number of experiments were made with poison baits against mole crickets in Trinidad. Wheat bran, rice bran, crushed corn and crushed rice were all found to be highly attractive to mole crickets and were used as diluents or carriers in baits. Rice bran is of local origin and generally easy to obtain. It is very much cheaper than and apparently just as effective as imported wheat bran. Both corn and rice are produced locally and are readily obtainable. When crushed they make effective diluents but are more expensive than rice bran.

The baits were offered to mole crickets in the laboratory, used in a special box experiment and applied in the field. In the laboratory glass battery jars 8¾ inches by 6¾ inches by 13 inches were used. Each jar was covered with a glass plate. The jars were filled to a depth of about 4 inches with finely sieved soil, on the top of which were placed uprooted tufts of savannah grass (*Axonopus compressus*). Known numbers of mole crickets were then added to each jar. In the box experiment a flat open box measuring 24 inches by 18 inches by 8 inches with a moveable ¼ inch wire mesh cover was used. The box was filled to a depth of about 4 inches with finely sieved soil and then planted with savannah grass. The surface of the grass was about 2 inches below the wire mesh cover. The grass was kept watered and infested with known numbers of mole crickets. In the field baits were applied to lawns, vegetable beds prior to planting and newly planted beds of tomatoes, cabbages and cauliflowers.

The following substances were used in poison baits:—Paris green, lead arsenate, calcium arsenate, metaldehyde, sodium fluoride, cryolite, sodium fluosilicate and barium fluosilicate. The arsenicals were used in the proportion of 6 ounces of the insecticide to 5 pounds of bran or crushed grain. Mole crickets fed quite readily on these baits in the laboratory and kills of 75 to 80 per cent. were obtained. In the field they appeared to be reasonably effective in controlling mole crickets.

Metaldehyde is an extremely effective poison bait against slugs. For the control of these pests it is normally mixed with bran in the proportion of 1½ ounces of metaldehyde to 5 pounds of bran and applied to the surface of the soil in small heaps at the rate of 20 pounds of the dry bait per acre. Mole crickets were given every opportunity of

feeding on this bait in the laboratory at the above concentration and also at the rates of 3 ounces and 6 ounces of metaldehyde to 5 pounds of bran. Although some of the bait was eaten no mole crickets were killed, and it was concluded (Callan, 1941) that metaldehyde is ineffective for the control of mole crickets.

Sodium fluoride, cryolite, sodium fluosilicate and barium fluosilicate were used in the proportion of 6 ounces of the insecticide to 5 pounds of bran or crushed grain. In the laboratory mole crickets fed readily on these baits and kills of 80 to 90 per cent. were obtained. These baits appear to be rather slower in their action than the arsenicals and required from 3 to 4 days to kill mole crickets under laboratory conditions. In the field they appeared to be effective in controlling these pests.

The physiological effect on the insect of poisons containing fluorine is not precisely known. After eating barium fluosilicate bait mole crickets exhibit a marked paralysis. This is first apparent in the abdomen and then gradually spreads through the whole body. After about two days movements become unco-ordinated with paralysis of first the hind legs followed by that of the middle and fore legs. Later paralysis of the mouth parts and antennae ensues, and, after 3 to 4 days, all movement ceases and death supervenes.

Method of Application of Poison Baits

In the preparation of poison baits the insecticide should be in the form of a very fine powder. When bran is used it should first be mixed dry with the insecticide. Sufficient water should then be added to give the bait a crumbly consistency. When corn or rice are used they should be fairly finely crushed so as to produce a rather coarse meal. This should then be moistened with water, and the insecticide finally added so that it adheres to the broken surfaces of the grains. In all cases the insecticide should be very thoroughly and evenly mixed with the diluent, and the bait should be of a crumbly consistency. It is essential to use the poison bait when freshly prepared, as moist bait quickly becomes mouldy and is then unattractive to mole crickets.

The bait should be broadcast evenly on the surface of the soil, preferably in the evening after heavy rain. It is recommended that the bait be applied whenever possible to vegetable beds prior to planting and a second application made when the beds are planted out. It should not only be scattered between and around the plants but also on pathways and round the edges of the beds. Normally the bait should be applied at the rate of 20 to 30 pounds of the dry poison bait per acre. The bait remains effectively toxic for several days, but heavy rain following application washes away most of the bait and necessitates further treatment.

Precautions in Using Poison Baits

Precautions should be taken to ensure that livestock including poultry do not have access to areas where poison baits have been applied. Poultry feed readily on baits prepared with bran or crushed grain, but domestic animals such as dogs and cats are apparently not attracted to such baits.

The fluorine compounds are in general less dangerous to use than the arsenicals, but they are nevertheless highly poisonous substances and can cause serious injury to the user. When preparing or applying poison baits containing fluorine, the normal precautions used in handling poisons should be taken. None of the insecticide should be inhaled or allowed to gain access to the mouth, and the hands should be washed thoroughly afterwards. Fluorine compounds, in addition to other harmful effects, may cause serious injury to the finger-nails, and these parts should be cleaned especially carefully after handling such substances.

General Recommendations for Control

For the control of mole crickets attacking lawns any method is advocated whereby these pests can be brought to the surface and then collected and destroyed. Carbon disulphide emulsion watered directly into the lawn is recommended for this purpose.

The most effective methods of controlling mole crickets in vegetable gardens are by the use of protective collars or poison baits. Large tough leaves such as those of mammee apple (*Mammea americana*), stiff waxed paper or metal cylinders are recommended as protective collars. The poison bait recommended is 6 ounces of sodium fluosilicate or barium fluosilicate to 5 pounds of bran or crushed grain applied at the rate of 20 to 30 pounds of the dry bait per acre.

Summary

1. The mole cricket, *Scapteriscus vicinus* Scudder, ranks as a major pest of vegetable gardens and lawns in Trinidad, B.W.I., while *Gryllotalpa hexadactyla* Perty is relatively rare.
2. The nature of the damage caused by mole crickets, their life-history and natural enemies, and methods of control are described.
3. Mole crickets attacking lawns can be controlled by bringing them to the surface with carbon disulphide emulsion or by other means and then collecting and destroying them.
4. In vegetable gardens protective collars placed around plants are effective in preventing attack. Large tough leaves such as those of mammee apple (*Mammea americana*), stiff waxed paper or metal cylinders are suitable for this purpose.
5. Results are given of experiments with poison baits. The fluorine compounds tested appeared to be rather more effective than the arsenicals. Metaldehyde bait was ineffective. Directions are given for preparing and applying poison baits together with precautions in using them. The bait recommended for use against mole crickets in Trinidad is 6 ounces of sodium fluosilicate or barium fluosilicate to 5 pounds of bran or crushed grain applied at the rate of 20 to 30 pounds of dry bait per acre.

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CARNAUBA WAX *

The carnauba palm is the source of the world's most valuable vegetable wax—carnauba wax—listed among Brazil's exports for more than a century. Although native to most of the country, only in the semi-arid Northeast area of Brazil does the tree produce extractable quantities of wax. From this region comes the world's entire supply.

The uses of carnauba wax are many. Picric acid for gunpowder, lipstick, sealing material for dry-cell batteries—into all of these goes carnauba wax. It is used in the manufacture of floor, shoe, and furniture polishes, gramophone records, sound film, electric insulators, soap, candles, lubricating oils and carbon paper. Wrapping paper, cardboard, textiles, and industrial machinery are waterproofed with it. Carnauba wax goes into various salves and ointments, artificial fruit, plasters, matches, cable coverings, paints and varnishes. A coating of the wax enables airplanes to increase their speed. Having three times the viscosity of beeswax, it is used to harden beeswax, ceresin, and paraffin.

The value of the carnauba palm, however, is not limited to wax. The trunk provides rural housing materials, furniture, pilings, fences, bridges, and fuel for industrial use. The bark is used for home fuel. From the leaves are made baskets, thatch roofs, hats, ropes, mats, and other woven products. The sap provides a wholesome tapioca and a fermented drink. Young shoots are used as the palmito cabbage, and the heart of the young palm provides a starch, similar to manioc (cassava) flour. From the pith comes a coffee-like drink. Stalks and other residue provide cattle fodder.

Classified botanically as *Copernicia cerifera,* the palm thrives in broad, dry valleys and along river banks, the largest stands being in the States of Ceara and Piauhi. The bark is rough, thick, and scaly; the flowers numerous and tiny; the fruit, growing in bunches, is green until ripe, when it becomes rust coloured. Carnauba wax comes from the serried, fanlike leaves, radiating from the crown of the tree. Giving the appearance of a coating of dust, the wax forms during the dry season, preventing excessive water evaporation from the tree. Drought increases the yield of wax, but severe drought over a period of several years may kill the tree. Young trees begin to produce wax after 8 or 10 years.

The wax harvest comes largely from wild trees. Harvest operations are carried on by primitive methods during the dry season, from September to December. The work is done by hired labourers, tenant farmers, or by moradores, semi-nomadic cattle raisers who move about in search of pasturage. Two cuttings are made each season, with a lapse of about 80 days between cuttings. With a knife attached to a long stick and curved like a sickle, the worker cuts the stems and collects the leaves as they fall to the ground. Care must be exercised in selecting leaves to be harvested. If very young leaves are cut the tree will slowly die; if fully matured leaves are cut they yield little wax. Selection is based on the position of the leaves on the tree. Young leaves grow upright, and then of their own weight bend outward and downward as they mature. Leaves pointing to the rising or setting sun, in what the natives call the " 6 o'clock " position, are old.

Cut leaves are sun-dried for three to five days during which their wax coating becomes a flour-like dust. Drying is done either in open fields where the wind causes a dust loss of 20 to 30 per cent., or in walled enclosures which permit exposure to the sun while affording protection from the wind. In a windproof shed the dried leaves are beaten to liberate the dust, which is placed in clay vessels and melted down into wax, or mixed with a small quantity of water and boiled. When dissolved, the wax is strained through a coarse cloth or wooden press to remove some of the impurities, and then allowed to cool. The solidified mass is broken into small pieces and packed in bags. New leaves yield a darker, less-valuable wax.—(*Agriculture in the Americas,* IV, 12, 1944.)

*See also *Trop. Agriculture,* XIII, p. 298, 1936.

MICROBIAL METABOLISM AND AGRICULTURE *

BY

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THIS paper (1) is designed to point out certain relationships between fundamental studies on microbial metabolism and the great basic science and art of agriculture, and that these advances in physiology, enzymology and physiological chemistry are significant not only in terms of human nutrition and human physiology and curative and preventive medicine, but also in farm production.

Obviously I am not called upon on an occasion of this kind to explore to the limits all the ramose diverticula of modern findings and theories relative to the uptake, synthesis and breakdown of substances useful or harmful to the microbial cell. Rather I should indicate those studies and advances which seem particularly promising in their application to non-microbial organisms. There is a great practical significance to the present and mounting knowledge on microbial metabolism.

Studies on microbial metabolism have stimulated a greater appreciation of the real unity of the basic characteristics of all protoplasm and the wide-spread uniformity of many of its activities. First an example: Until comparatively recently the ability of plants to fix carbon dioxide was conceived to be quite dependent upon the presence of chlorophyll. Then Winogradsky and others found that certain microbes were able to fix carbon dioxide without chlorophyll, and so living things became segregated into those which could not use carbon dioxide and those which could—the latter being subdivided into those which required chlorophyll and light (the photosynthetic forms) and those which utilized reduced inorganic compounds such as hydrogen sulfide or ammonia as hydrogen donors in the reduction of the carbon dioxide. Then came the brilliant work of Gaffron, van Niel and others, which revealed that some kinds of organic compounds may replace inorganic when used by certain so-called chemosynthetic bacteria. And then it was found that the exact period during which a green plant was illuminated did not necessarily precisely coincide with the period during which carbon dioxide was being fixed. And then the pioneer work of Werkman and Wood and their colleagues showed that certain bacteria, in the first instance the propionic acid bacteria, can and do fix carbon dioxide, even though they are included in the heterotrophic group. This was revolutionary thinking, quite against the traditions of the tests. But these men by use of the isotopic technique not only confirmed their earlier findings, but showed the channel through which in this case the carbon dioxide enters into and becomes a part of an organic molecule. Then it seemed that we might recognize three groups of carbon dioxide-fixing organisms, the photosynthetic, the chemosynthetic, certain heterotrophs. But what about the animal kingdom which is entirely heterotrophic? Soon came the evidence that animal tissues likewise may assimilate carbon dioxide, even the tissues of the human body. Through this sequence of studies we have a most surprising and emphatic demonstration of wide-spread uniformities in metabolism of plants and animals, of the essential unity of protoplasm. Studies on bacterial metabolism are bringing us to an understanding of how the corn plant manufactures starch. True, one channel or method only whereby carbon dioxide gets into an organic molecule has been demonstrated for certain bacteria. But it seems improbable that the one first discovered is either the only or necessarily the most important channel or mechanism of carbon dioxide fixation by plants. When we look back upon the development of our knowledge in this field we realize that a part of our difficulty has been slowness to recognize the applicability of certain principles of physical chemistry, such as the reversibility of chemical reactions. May I again emphasize that studies in bacterial metabolism, studies on forms of life possessing no photosynthetic powers, are giving answers to phenomena which are fundamentally basic to agriculture. The apparent ease and facility with which the agricultural and forestry crops manufacture carbohydrates from carbon dioxide and water has irritated and baffled the plant physiologist and the agricultural scientist. Apparently studies on microbial metabolism are furnishing needed keys and tools.

We are woefully deficient in our knowledge of certain phases of nitrogen metabolism of living cells. One of the most puzzling problems since the beginnings of modern chemistry has been the fact that although nitrogen is an essential element in all living protoplasm, and though elementary nitrogen is almost omnipresent, relatively few cells seem able to bring about this fixation and utilization. Nitrogen fixation is one of the really fundamental problems of agriculture. We know that certain free-living soil bacteria and algae can fix nitrogen and build it into protoplasm. We know too that certain bacteria and perhaps other micro-organisms in symbiosis with higher plants can also fix nitrogen. Upon these two facts, so far as our present knowledge goes, we

(1) Address of the retiring vice-president of Section O—Agriculture, American Association for the Advancement of Science, Cleveland, Ohio, September, 14, 1944.

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base our whole theory of native soil fertility. The Haber process of nitrogen fixation and its later developments have conceivably made possible an agriculture freed from a base of microbial nitrogen fixation. But far more nitrogen is fixed microbially now, and probably will continue to be, than will be fixed by artificial means. One hesitates to predict, but this situation will probably continue until we have learned just how the microbe fixes the nitrogen. Progress is being made. The work of Virtanen and of Wilson and their collaborators has yielded and is yielding results. It is probable that presently the technique of fixation and the nature of the initial compound or compounds will be clear. What this may mean for practical agriculture is not entirely certain. But we shall know a mechanism which has long baffled us and which may clear up the long-term enigma of the nitrogen-fixing powers of the *Leguminosae* and of some other groups of higher plants.

The chemical changes which micro-organisms bring about in their environment are of real significance in agriculture as well as in other fields. Our knowledge of the steps which are required and of the tools which are used by the organism is gradually being unravelled. We live in a welter of cycles named after this and the other individual; chains of chemical transformations which have been suggested as hypotheses. And each comes nearer to giving us a clear picture of what the cell is doing, what tools it uses and from whence the energy is derived to keep the machine functioning.

The microbial cell has many advantages in the study of certain physiological processes over the cells of multicellular forms. One may have uniform cells, cells of various growth stages, with or without chlorophyll, and with an astonishing gamut of uniformities with which to work. The extension to study and confirmation in physiology of higher plants is proving most useful in an understanding both of normal and abnormal cell physiology.

Micro-organisms have long been used as food, but their production as crop plants has only recently been initiated and somewhat developed. The most outstanding and consistent of the physiological differences between animals and plants in general is the lack of ability on the part of animals to utilize nitrogen in a form simpler than an amino acid, or at least an amine. Most plants on the other hand can utilize ammonia and even nitrates and other simple nitrogen compounds. From the standpoint of agriculture, in most of our agricultural economies, there is an over-balance of carbohydrate feeds as contrasted with protein, particularly in production of meat, milk and eggs. It is true we may apply the nitrogen to the soil and get crop increases, but with still some inbalance. In recent years there has come the thought that it might be practicable to convert the excess carbohydrates, lignins, &c., into proteins through the intermediation of micro-organisms. Several examples of this tendency may be cited. Previous to the outbreak of this war, a considerable amount of German literature appeared on the subject of developing supplementary protein feeds from cheap carbohydrates and synthetic nitrogen. The fact was established that the yeast cells contained in brewers-grains, distillery slops, &c., make a distinct contribution to the protein value of these as feeds for domestic animals and birds. By shift of emphasis cheap carbohydrates were sought on which to grow yeasts primarily for their nutritive value. Wood waste, sawdust, was hydrolyzed, syrup extracted, synthetic nitrogen (ammonia) added and yeasts grown under appropriate conditions of aeration. A reasonably complete conversion of the nitrogen into protein useful for feeding hogs, poultry and other domestic animals resulted. This, of course, in the interest of a self-sufficient economy.

More recently we have been told of the possibility of utilizing the yeast as a human food, not simply as a supplier of certain vitamins, but, as the newspapers had it, in the form of synthetic beef steaks. Work of the Lindegrens in hybridizing the yeasts to get better varieties may well be significant.

But yeasts constitute a tiny fraction of the range of micro-organisms and higher fungi that can attack carbohydrates, even lignins, and which can utilize ammonia with consequent production of proteins. Some development is possible in our post-war world in the utilization of these materials together with our excess production of synthetic nitrogen in the manufacture of cattle and hog feed. Xylans are available in abundance; the production of xylose syrups is feasible. Micro-organisms and fungi are known which can utilize one or the other or both. Great quantities of coarse fodders, cull potatoes, &c., might with some clever planning be converted into high protein feeds, into protein of good quality. We know comparatively little about the fundamental metabolism of most micro-organisms and fungi. But there is little doubt but what a fungus agriculture might put to good use a great amount of present waste and cull material.

Recently we have become increasingly aware that the microbial flora already present or which may be developed in the body of certain animals may be distinctly useful. We now know that urea can at least in part replace proteins when fed to certain ruminants, including the dairy cow. Apparently there exists in the paunch of these animals a microbial flora which utilizes on the one hand the carbohydrates of the food but metabolizes also the urea into the protein of its own cells. Probably the organisms are bacteria. But just how the bacterial protein is utilized by the animal we are not quite sure. Much work is needed by a combination of bacteriologists, protozoologists and physiologists. We know that not only does the paunch contain a rich flora of bacteria but an unusual and startling fauna of protozoa. The recent success of Hungate (2) in cultivating a *Eudiplodinium* from the paunch of cattle is a

(2) *Biol. Bull.*, 83 (3): 303-319, 1942.

challenge to further work. These obligately anaerobic ciliates were cultured for 22 months in a medium containing inorganic salts and pulverized dried grass and cellulose. This author shows that not only does this protozoan digest cellulose and contain the enzyme cellulase, but that the synthesis by protozoa of proteins in the paunch supplies perhaps one fifth of the protein requirements of the animal. Here we have an intricate symbiotic mixture of micro-organisms, protozoa feeding on bacteria and cellulose; and the cow utilizing both as protein food. Here certainly we will find eventually close relationships between microbial metabolism and agriculture.

Brilliant work is being done on the characterization of foods and feeds on the basis of the adequacy of their proteins, their amino-acid makeup and their association with vitamins and accessory growth substances. Agriculture benefits from both sides: it produces the food, and it uses the feeds. Analyses for amino-acid content and particularly for vitamins and other accessory growth substances are increasingly important. Here again microbial metabolism is playing an important rôle. Many of the bacteria are able to synthesize all the various growth accessory substances which they require. Some produce vitamins to such a degree as to be significant when used as foods or feeds, but many others are " born " deficient in ability to produce certain of these. This is particularly true of species that have become highly adapted to a particular environment. Such are to be found among the bacteria parasitic on plants and animals and others which grow normally on fermenting plant materials. The environment has supplied their need for auxins or vitamins, &c. We find them difficult in consequence to culture, particularly on a synthetic medium. It was not at first clearly recognized that certain of these growth accelerants, &c., required by these organisms were identical with the vitamins. And now we find that these organisms are becoming most useful tools in evaluating the vitamin content of foods. And the same is true for the amino acids. Some organisms can synthesize from the simplest materials all the amino acids which they need. Others can not. There is good evidence that such organisms lack some essential part of the enzyme system necessary for the synthesis of some particular amino acid or even several amino acids. Unless these are supplied ready manufactured, the cell can not grow. And, other conditions being favourable and standard, the rate of increase in the microbial cells is an easily ascertainable mathematical function of the amino-acid content of the medium. The rate of growth becomes a tool for determining quantitatively the amino acid.

Our armamentarium for this purpose has been enriched from two principal sources, the isolation of organisms from special environments and the development of mutations. The latter has been most extensively studied and developed by Beadle for the fungus *Neurospora*. Various mutations have been developed which reveal certain enzyme deficiencies. In some cases fruiting is inhibited by lack of certain substances in the medium. It is evident that those scientific laboratories which serve agriculture have now a new array of tools; biology has come to the aid of chemistry in much the same fashion as in the past chemistry has tooled biology. Facility in determination of the quality of foods and feeds will have its abundant fruition in better nutrition for man and animal.

For decades there has been accumulating a considerable microbial literature on the general topic of antibiosis and of staling substances. Observation has long shown that certain types of organisms grow better together, but in other cases one organism may be antagonistic to another. It is common observation that when growing upon a culture medium mold hyphae show either positive or negative chemotropisms. A microscopic view of the margin of certain mold colonies shows that the branches of the filaments as they originate quite accurately bisect the angle between the adjacent hyphae. Evidently the young hyphae grow in the direction of the lowest concentration of excretory products, or conversely show a negative chemotropism with reference to the excretory products of the plant itself. When two colonies approach each other in growth, they are mutually inhibited and do not grow together; *i.e.* they remain separated. Then, too, one species may inhibit the growth of another. The medium on which an organism has been grown may be positively inhibitory for another. The pyocyanase produced by *Pseudomonas aeruginosa*, actively lytic for certain other bacteria, has long been proposed as a therapeutic agent. Recently major attention has been drawn to these staling or antibiotic or bacteriostatic or bacteriolytic substances when it has been found that some were far more toxic or inhibitive to certain pathogenic organisms than they are to the tissues of the animal body, and we had the discovery and development of penicillin and the various other microbial bacteriostatic or bacteriotoxic substances. And more recently we are gaining an insight into what essential segments of the enzyme systems are put out of commission. We have been so impressed by the efficiency of penicillin in human therapy that we may overlook the agricultural significance of future developments of this type in study on microbial metabolism. The utilization of therapeutic agents in veterinary medicine will follow the regular course of human medicine. But there is a wide-open field in the control of plant diseases, particularly seedling diseases, damping-off, &c. We in agriculture are coming to a realization that fungi attacking roots and seedlings play a great rôle in limiting crop production. Certain of the pythiaceous fungi are particularly significant. When grown on culture media inhibition by various fungi is readily observed. A whole field of phytic therapeutics is opening up. The antagonisms and interactions of the fungi and the bacteria make possible the production, isolation and identification of anti-

biotics, some of which may be useful, and at least will give us clues to work with in our efforts to develop synthetic plant treatments and to explore more adequately the relationship of chemical structure to therapeutic efficiency and toxicity.

Another type of advance which we in agriculture view with great interest is the progress that is being made in determination of the paths of microbial synthesis. I remember years ago—now nearly four decades ago—hearing Dr. Nef, then head of chemistry at the University of Chicago, predict that largely as a result of the analytic studies underway, adequate techniques of synthesis of the carbohydrates would be commercially feasible within a decade. But it has not yet been accomplished. The problem of synthesis is far more complex than originally surmised. But we are making progress. By use of enzyme preparations we are able to carry on these syntheses apart from the living cell. Witness the recent success of Barker and his collaborators in making use of an invertase-free sucrose-phosphorylase from the bacterium *Pseudomonas saccharophila* in the synthesis of sucrose from glucose-phosphate and fructose. We are beginning to see how old Mother Nature is able with little apparent effort to synthesize the complex compounds which she produces so abundantly in every green plant. And our microbial studies are increasingly significant.

Knowledge of microbial metabolism is bound eventually to crack the great mystery of virulence in disease production. We know rather accurately what changes certain bacteria produce upon their environment *in vitro*, but our efforts to correlate with what happens *in vivo* have not been particularly successful. One of our difficulties has been that in most cases we could not readily determine degrees of virulence as contrasted with degree of resistance or immunity. Recently it seems that we are on the track of techniques which should help in unravelling the difficulty. We have learned that measurement of virulence of an organism by the determination of the size of the lethal dose is not entirely satisfactory. Some studies underway on maize show one advantageous technique. Inbred strains of maize become highly homozygous, and the individuals of each strain react with a high degree of uniformity. And by choice of these inbreds one may secure a regular gamut of resistance to certain diseases. Particularly interesting is that caused by *Pseudomonas stewartii*, the Stewart's disease of corn. Some strains of corn are highly resistant to infection, others very susceptible. Furthermore, the causal organism, Stewart's bacterium, can be caused to mutate, and one may secure strains varying widely in attacking power of virulence. We have fixed standards to measure virulence ; we have strains which mutate when grown in culture media. But we need vastly more knowledge of the slight metabolic differences among these microbial strains. Variations in virulence presumably must have a basis and be completely correlated with variations in the microbial metabolism. We are gaining command of the tools which are needed to detect these changes. When once we know the metabolic differences among these strains, we shall be for the first time in position to know what constitutes immunity. In this whole series of studies, agriculture will have much of profit.

Agriculture has tremendous interest in the changes which may be effected by micro-organisms in their chemical environment. The studies on basic microbial metabolism are yielding the keys to understanding of the exact chain or sequence of events in the great maze of fermentations and products of microbial change. Higher plants produce vast stores of polymers based upon the hexoses, and upon these most of our present fermentation industries are based. But plants also produce vast stores of polymers based upon the pentoses as well. Pentose sugars could easily be made available in large amounts if we knew satisfactory fermentative uses for them. The sugar xylose is readily secured from many agricultural products. It is not utilized by our domestic animals. It can be attacked by certain micro-organisms. But we need more and better basic information on microbial metabolism before we can satisfactorily unlock effective utilization.

Let's look for a moment at the industries and potentialities based largely upon the use of hexose sugar.

Alcoholic fermentation has long been studied intensively. Pasteur showed the relationship of the yeast to the process ; Harden started our modern development of knowledge relative to the enzyme systems in all their complexities. While there is much still to be done, it probably is safe to say that more is known relative to the changes from sucrose or starch to alcohol and carbon dioxide than to those inherent in any other metabolic series. In many respects the studies on this sequence of changes have been basic to our understanding of many other intra-cellular types of changes. In these studies agriculture has a tremendous stake.

Before exploring this phase of fermentation further, let's look for a minute at the sources from which we may secure the carbon for the multitudinous organic compounds with which civilized man is increasingly concerned. We live in an ocean of air-containing carbon dioxide, and we have access to the oxidized carbon given off in flue gases, and to that found in the great deposits of carbonates in the earth. Carbon dioxide itself is, of course, increasingly useful to man as such. But carbon in most cases is in reduced carbon compounds in which there are carbon-to-carbon linkages, or in which there is hydrogen or hydroxyl, &c. Technology has methods of reducing the carbon of carbon dioxide, but for all practical purposes the organic compounds of modern life have their origin in the growth of plants. The marvelous precision with which plant life takes up carbon dioxide and reduces it and combines it has proved thus far to be our

cheapest and most satisfactory technique. True, we may start with coal or with petroleum, but these are but the fossilized products of plant growth. A major economic concern of agriculture is just this: What are the relative efficiencies in securing the organic compound needed by civilization from coal, from petroleum and from the products of farm and forest? There are broad areas in which each has an advantage. In petroleum and in coal there are already present many useful compounds which only require extraction; many of the products of agriculture, particularly for use as food and feed, have not been and probably can not be successfully duplicated. But there are considerable areas where relative advantages of crops, coal and petroleum are not so clear. For example, one may produce alcohol synthetically from coal, from petroleum, from agricultural products or by fermentation from agricultural products. Concretely at present it breaks down into competition between fermentation alcohol or synthetic alcohol from coal and petroleum. For some decades organic chemistry was coal tar chemistry and ring compound chemistry, and more recently it has been petroleum chemistry and straight chain chemistry. You will recall the ballyhoo two years ago about how our synthetic rubber problems would be promptly settled by petroleum. The paper chemistry of butane or ethylene to butadiene to rubber is beautiful to behold. But American tanks and guns and jeeps are in action all over the world because yeast made alcohol from sugar and chemists made this fermentation alcohol into butadiene and this into synthetic rubber It is true that in this great crisis in motorization and mechanization it was the zymotechnologist and not the petroleum chemist that made rubber supplies possible and reasonably adequate. May I repeat my point. There are many areas in which needed organic compounds can be produced either by fermentation, *i.e.*, by microbial activity or by chemical synthesis. The calm assumption of some of our chemist friends that huge retorts and distillation devices and catalysts and high pressure, &c., constitute the answer should be regarded in many cases with some scepticism. Economics must determine what process is most efficient. The fact that quinine has been synthesized at Harvard recently doesn't mean that the Cinchona tree may not be the most satisfactory source of the drug-any more than the demonstration of an enzyme system that can combine fructose and glucose into sucrose means that we will quit producing sucrose from the sugar cane in Cuba. I am insisting that a practical chemical economy in the future depends quite as much upon our exploration of the fundamentals of microbial metabolism as upon the exploration of petroleum chemistry, conceding the vast importance of the latter. A substantial part of the economics of agriculture, of the future of agriculture, is bound up in the adequate exploration of microbial metabolism.

Fermentation products frequently have an advantage in that they are relatively pure, or may be readily purified. Commonly they are not mixed with isomers. For example, 2—3 butylene glycol is a product which can be produced commercially by fermentation with facility. But there are several isomers of this compound which show interesting differences in behaviour. One apparently would make a good anti-freeze for your automobile radiator, the others will not. Chemical synthesis is apt to yield a mixture with great difficulty in separation. But certain bacteria produce the desired isomers practically pure.

The stake of agriculture in the problems of chemical utilization are considerable and material. Right now millions of bushels of grain are being converted into rubber. To what extent may agriculture look to fermentation industries in the future to assist in relieving us of great surpluses of grains, surpluses which are absolutely inevitable without major changes in world economy, changes which at the best can be brought about but slowly? Crop residues likewise must be studied directly as competitors of coal and petroleum in the future development of our agricultural economy. Fermentation products will increasingly constitute the raw materials for chemical synthesis and transformation.

In summary, microbial metabolism, microbial nutrition, real continuance of research in fundamental fields relative to the physiology of micro-organisms, are of quite as much significance to agriculture as to medicine or to biology as a whole. We are on the verge of new advances which may have the most far-reaching consequences to standards of living and to civilization.

FLAME CULTIVATION

Some 70 flame cultivators of a type resembling those in use on cotton plantations were used experimentally on Glenwood and Woodlawn estates, Louisiana, in 1943 and again this year. Each 2-row machine dealt with 100 to 200 acres of cane depending on the density of the weeds and grasses, and cost 60-80 cents per acre for each flaming, this figure including two men, tractor operation and depreciation and burner fuel. Opinion established as the result of three trials is that flame cultivation is proving indispensable during the existing period of acute labour shortage, most operators believing that under normal labour conditions this means will prove more efficient and economical than hand hoeing, the cost of which is estimated at $6.00 per acre with heavy infestation. (*Intern. Sugar J.*, 1944, Vol. XLVI, p.280.)

The Editor is prepared to consider signed articles for publication in *Tropical Agriculture*. Such articles should normally vary between 1,000 to 6,000 words and may be illustrated if desired.

PLANT PATHOGENS AND MICROBIAL COMPETITION IN SOIL *

Among many examples of competition or antagonism between species of soil organisms particular interest centres around the survival of plant-pathogenic organisms among an otherwise normal soil population. A notable example of this is afforded by the case of *Ophiobolus graminis*, the fungus causing "take-all" disease in wheat. S. D. Garrett (1) ascribes the observed differences in infectivity of this soil-borne organism to relative differences in the competition between the pathogen and normal soil organisms for the available nutrients in the soil. A. Lal (2) associates the different rates of disappearance of the mycellium of *Ophiobolus graminis* from infected soils with differences in soil type and with the presence of other organisms, *e.g.*, *Trichoderma lignorum*. Metabolic products of some of these organisms are shown to be toxic to *O. graminis*. Later work of Garrett (3) indicates that the nutritional status of the wheat plant itself is a factor in the infectivity of the fungus.

A somewhat similar phenomenon is recorded by A. A. Hildebrand and P. M. West (4) in a study of root-rot in strawberry. It is shown that changes in the microbiological equilibrium of the rhizosphere of the plants resulting from the incorporation of manure or cover crops with infected soil are directly related to the severity of root-rot. The decomposition of certain types of organic matter, *e.g.*, soya-bean tops, in soil is followed by rapid reproduction of harmless organisms at the expense of harmful types and the attack on the strawberry plants is correspondingly limited. Other cover crops, *e.g.*, timothy or red clover, have no such effect. In soils thus treated the occurrence of the nematode *Pratylenchus pratensis* is probably related to the observed effects. H. Katznelson, (5) in a study of the survival of various micro-organisms in sterilised soil, obtained evidence of the inhibitory action of bacteria, actinomyces, and fungi on organisms which contribute indirectly to plant nutrition, *e.g.*, *Azotobacter chroococcum*, *Actinomyces cellulosae*, *Bact. megatherium*, and also on pathogenic organisms such as *Rhizoctonia solani* and *Helminthosporium sativum*.

Another instance of apparent antagonism between species of soil organism is noted by A. L. Brodski (6). In this case the antagonism is probably due to the production of a toxin by one organism rather than to nutritional competition. Tomato plants become infected with *Verticillium* wilt when grown in aqueous media to which pseudospores of *Verticillium dahliae* are added. If the infusorium *Culpoda* is also added to the medium spores of *V. dahliae* do not germinate and the plants show no symptoms of wilt. Further, the addition of cultures of *Culpoda* to wilt-infected soil caused a marked diminution in the number of plants infected. Other soil organisms, *e.g.*, *Bac. mesentericus* and *Bac. fluorescens*, produced similar though less intense effects on the pathogenic fungus. S. A. Waksman and H. B. Woodruff (7) describe the insolation of a new soil organism, *Actinomyces antibiotica*, which produces actinomycin, an anti-bacterial substance which, even in minute concentrations, inhibits the growth and fixation of nitrogen by *Azotobacter* and also affects certain fungi. The active principle is shown to contain a bactericidal and a bacteriostatic component.

In rhizospheres of varieties of flax susceptible to wilt and those of tobacco plants susceptible to root-rot, M. I. Timonin (8) finds greater numbers of micro-organisms than in those of the corresponding resistant varieties. In the case of flax root, excretions are shown to contain hydrocyanic acid which brings about a suppression of the pathogenic species and a corresponding increase in relatively harmless organisms. (9)

In contrast to the above, C. J. Lind and P. W. Wilson (10) describe a case of apparent beneficial association of two bacterial species. The fixation of nitrogen by *Azotobacter vinelandii* is much increased by *Clostridium pasteurianum* grown in the same substrate, the effect being conditioned by the amount of available iron present.

The complex interplay of microbial species and that between plants and soil organisms presents a wide field of study and seems likely not only to increase our knowledge of the biochemistry of soil organisms, but also to open another line of approach to the general problem of increasing the productivity of soil.

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*Abstracted from the section on "Soils and Fertilizers" by A. G. Pollard, Reports of the Progress of Applied Chemistry for 1943, issued by the Society of Chemical Industry, London.

A NEW ORANGE DISEASE IN BRAZIL

According to an article in *Agric. Amer.*, 3: 177, the rootlet rot disease, from which the orange groves budded on sour-orange stock have been suffering in the northern parts of Argentina since 1932, is now found in all the important orange centres of Brazil. The symptoms, which appear rather slowly, consist of the leaves turning chlorotic and being shed, followed in some cases by a secondary growth of very small leaves.

CHEMICAL NOTES

(Compiled by the College Department of Chemistry and Soil Science)

The Role of Magnesium in Plant Nutrition

Abstracted from the section on "Soils and Fertilisers" by A. G. Pollard, Reports of the Progress of Applied Chemistry for 1943, *issued by the Society of Chemical Industry, London.*

THE somewhat varied effects of magnesium deficiency on different crops suggest that, as in the case of calcium, the "unbalance" between magnesium and other nutrients may be as important as an absolute deficiency in plant nutrition. This is suggested by observations of B. T. Cromwell and J. G. Hunter (1) on a chlorosis of tomato attributed to magnesium deficiency but occurring on a soil containing a reasonably high proportion of exchangeable magnesium. The disorder failed to respond fully to injection of magnesium into the plants. A possible explanation of the phenomena is that high K/Mg ratios in the soil solution tend to restrict the intake of magnesium. Further investigations of magnesium deficiency at Long Ashton are reported by T. Wallace (2) in the case of Brassicae.

Absolute deficiency of magnesium in the plant restricts the photosythetic system and therefore disturbs the production of carbohydrates; in addition, magnesium appears to be linked with seed production. In citrus fruits the deficiency causes bronzing of leaves, and M. Peech (3) records a direct relationship between the exchangeable magnesium in soil and the occurrence of bronzing. In magnesium-deficient grapefruit examined by F. W. Cowart (4) the proportions of total solids and sugars were much below normal. Similarly in melons high sugar content is favoured by applications of magnesium to the soil (5). According to B. R. Fudge (6) fruit formation in grapefruit involves the translocation of magnesium and other mineral constituents from adjacent leaves into the fruit, the effect being more marked in seeded than in seedless fruits. Inadequate supplies of magnesium cause bronzing of leaves in seeded fruit but much less generally in seedless fruit.

The actual requirement of magnesium by various crops is small; it is normally maintained by the magnesium supplied in ordinary fertilisers, *e.g.*, superphosphate, potassium sulphate, or dolomite (7).

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Effect of Mulching on the Soil

MULCHING is a recognized method of conserving soil moisture, but often several other effects of the treatment are noticeable. This is not, of course, unexpected when the mulch consists of organic material containing soluble plant nutrients in greater or less amount.

I. W. Wander and J. H. Gourley (1) found that mulching with straw increased the contents of potassium, calcium, magnesium, phosphorus and boron in the soil, the effect being most marked for potassium, while H. Painter and G. F. Potter (2) report that with young tung trees mulching reduced signs of potassium deficiency, and C. E. Baker (3) found a mulch as effective as dressings of muriate of potash in increasing the potassium content of apple and peach leaves. These results may not be due entirely to potassium supplied by the mulch, as C. E. Baker (4) found that mulching with cinders or glass wool increased the potassium content of apple leaves, possibly because under the mulch a concentration of feeding roots near the soil surface, where potassium concentration is highest, occurred. Mulching with poor hay, also with apples, encouraged the production of surface-feeding roots in addition to increasing soil moisture (5).

The effects of mulching, however, are not always beneficial, and L. P. Latimer and A. P. Percival (6) found that although hay or seaweed mulches, as compared with grass covering, increased growth and fruit sizes in apples, sawdust used as a mulch did not have this effect, but did increase fruit and decrease leaf colour, suggesting that it had indeed a slight nitrogen deficiency. W. A. Johnson (7), using sawdust as a surface mulch for tomatoes, found that it decreased the soil nitrate content slightly and when incorporated in the soil, as mulch materials usually are eventually, depressed the soil nitrate appreciably so that heavier nitrate applications were required. The sawdust conserved soil moisture and caused the soil to be less compact, but repeated sawdust mulches may have undesirable effects. L. M. Turk and N. L. Partridge (8) found peat unsatisfactory as a mulch as it prevented light rain from reaching the soil, while loss by evaporation from the mulch continued. These ill-effects were not found when the mulch used allowed free percolation of water, and gravel, straw and sawdust were all effective in this respect.

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